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Session VI. Airborne Doppler Radar / NASA

NASA Airborne Radar Wind Shear Detection Algorithm and the Detection of Wet Microbursts in the Vicinity of Orlando, Florida

**Dr. C. Britt, Research Triangle Institute
E. Bracalente, NASA Langley Research Center**



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**NASA Airborne Radar Windshear Detection Hazard Algorithm and the
Detection of Wet Microbursts in the Vicinity of Orlando Florida**

**Charles L. Britt
Research Triangle Institute
Research Triangle Park, NC 27709**

and

**Emedio Bracalente
NASA Langley Research Center
Hampton, VA 23665**

**Abstract for Proposed Technical Talk for the
Fourth Combined Manufacturers' and Technologists'
Airborne Wind Shear Review Meeting
Williamsburg, Virginia
April 14-16, 1992**

Abstract

The algorithms used in the NASA experimental wind shear radar system for detection, characterization and determination of windshear hazard are discussed. The performance of the algorithms in the detection of wet microbursts near Orlando is presented. The talk will also review various suggested algorithms that are currently being evaluated using the flight test results from Denver and Orlando.

**NASA AIRBORNE RADAR WINDSHEAR DETECTION HAZARD ALGORITHM
AND THE DETECTION OF WET MICROBURSTS IN THE VICINITY
OF ORLANDO FLORIDA**

Charles L. Britt, Ph.D
Research Triangle Institute

Emedio Bracalente
NASA Langley Research Center

VIEWGRAPH TITLES

Slide 1 -

Introduction - NASA Airborne Radar Windshear Detection Hazard Algorithms and the Detection of Wet Microbursts in the Vicinity of Orlando Florida

Slide 2-

Example of a hazard index display from the NASA experimental windshear radar system. The algorithms to be discussed are designed to provide for timely windshear hazard alerts in the presence of ground clutter with no false alarms triggered by the ground clutter.

This hazard map is from flight data taken at Orlando, Florida on 6/20/91 and represents a wet microburst (Event #143) with a peak hazard factor of approximately .15. The subsequent flight of the aircraft through the microburst confirmed the hazard index through in-situ measurements. Agreement between the radar predictions and in-situ measurements was excellent.

Slide 3-

Techniques used in the NASA experimental radar to enhance the detection of a windshear hazard.

Slide 4-

Example of a plot of received power level vs. radar range showing the operation of the fast-acting radar AGC and the wide dynamic range seen along a range bin of the radar. Data from Orlando flight through microburst event #143.

Slide 5-

Chart showing various signal processing techniques that are being evaluated to separate the ground clutter and weather signals. The flight data is processed using various combinations of these processing techniques.

Slide 6-

Example of the Doppler spectrum obtained in range bin #47, frame 366 of Orlando event #143 (a wet microburst penetration). The mean wind velocity is approximated 6 m/s.

In processing the radar data, a 2-pole time-domain IIR filter was used with no data weights. The ground clutter is located at frequency line #65.

Slide 7-

Doppler spectrum taken under the same conditions as slide 6, except that Hann data weighting is used.

Slide 8-

Doppler spectrum taken under the same conditions as slide 6, except that FFT processing, Hann data weighting and spectral line editing is used.

Slide 9-

Doppler spectrum taken under the same conditions as slide 6, except that autoregressive (AR) processing, Hann Data weighting, and spectral line editing is used.

Slide 10-

Radar velocity map of microburst event #143 using a 2-pole IIR filter with Hann data weights and time-domain pulse-pair velocity estimation.

Slide 11-

Radar velocity map similar to slide 10 except using a spectral domain (FFT) filter (line editing) with spectral domain pulse-pair velocity estimation.

Slide 12-

Criteria for determining a valid velocity measurement in each range bin.

Slide 13 -

Algorithms used for calculation of the hazard factor.

Slide 14-

Plot illustrating the technique of least-squares hazard estimation. Five wind velocity measurements along a range line are used to estimate the slope of the velocity/range line which is proportional to the radial hazard index. In some cases, a weighted least squares technique is used whereby the velocity measurements are weighted by the value of spectral width. Measurements with smaller values of spectral width are given more weight in the slope calculation. This calculation is made for each range bin along a range line to provide an estimate of hazard for each range bin.

Slide 15-

Algorithms used to determine the extent of the hazard.

Slide 16-

Technique for determining the area and centroid of a hazard region as it appears on the radar map. The hazard region is a region of the radar map where the total hazard index is above a threshold value ($\sim .105$)

Slide 17-

Criteria used to display windshear alert on the radar display.

Slide 18-

Summary of the various thresholds used in processing flight data. The set of baseline thresholds given in the chart provide good results in the detection of windshear hazards and the elimination of false alerts. These thresholds are still under evaluation.

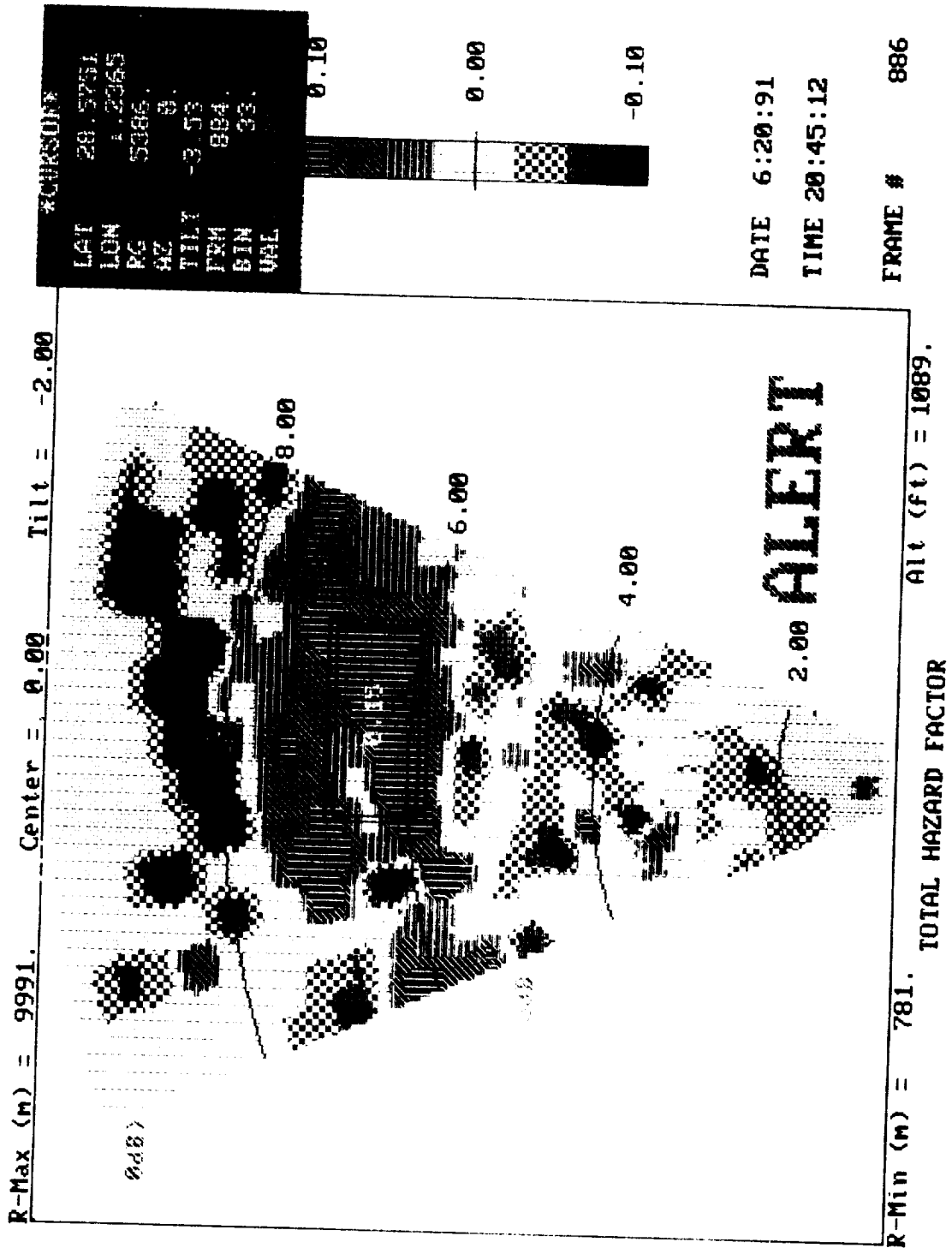
Slide 19-

Conclusions from evaluation of signal and data processing algorithms to data.

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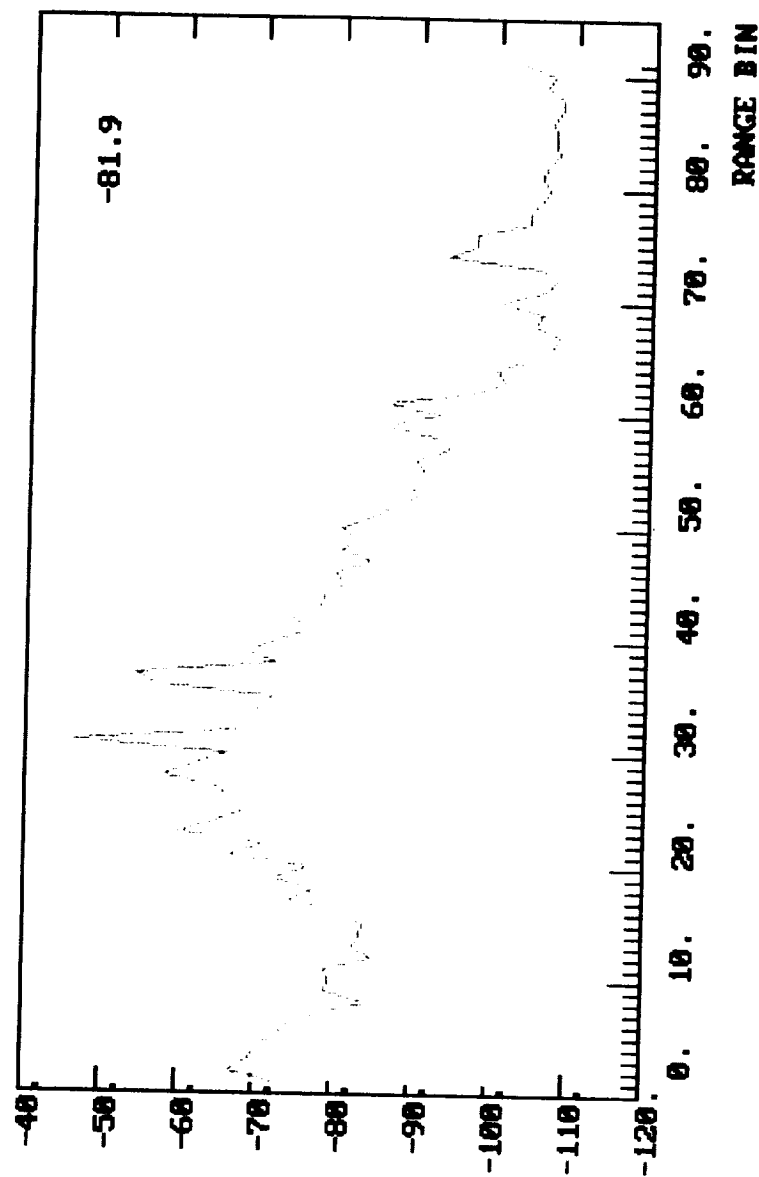


DETECTION OF HAZARD

- Independent AGC for each range cell with large dynamic range.
- Range limiting.
- Antenna tilt control.
- Stationary ground clutter filter.
- Weighted least squares hazard estimation.

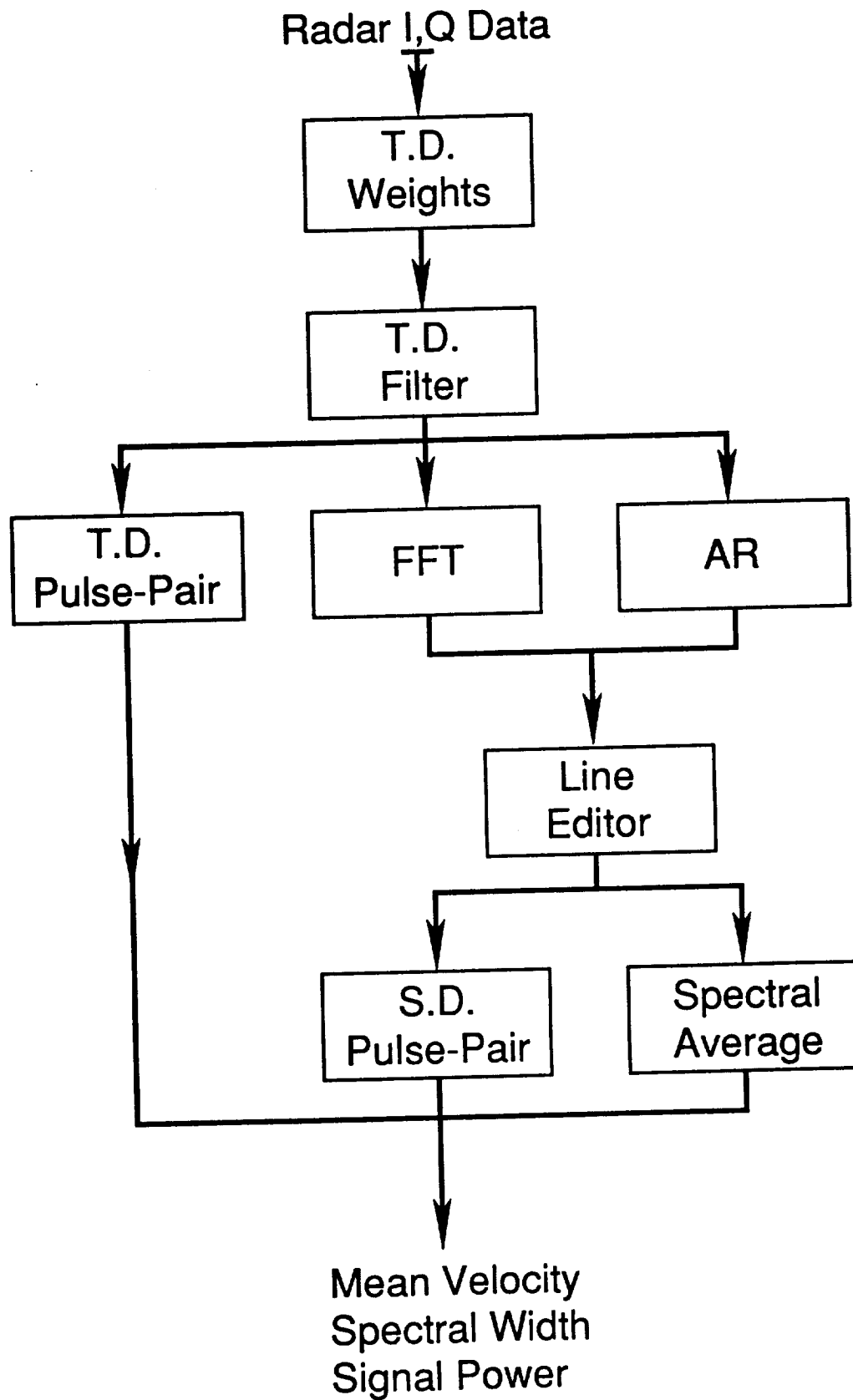
FRAME # 464
TILT = -2.8
ANT AZ = -4.8

POWER LEVEL (dBm) RG-MIN (M) = 781. RG-MAX (M) = 13876.



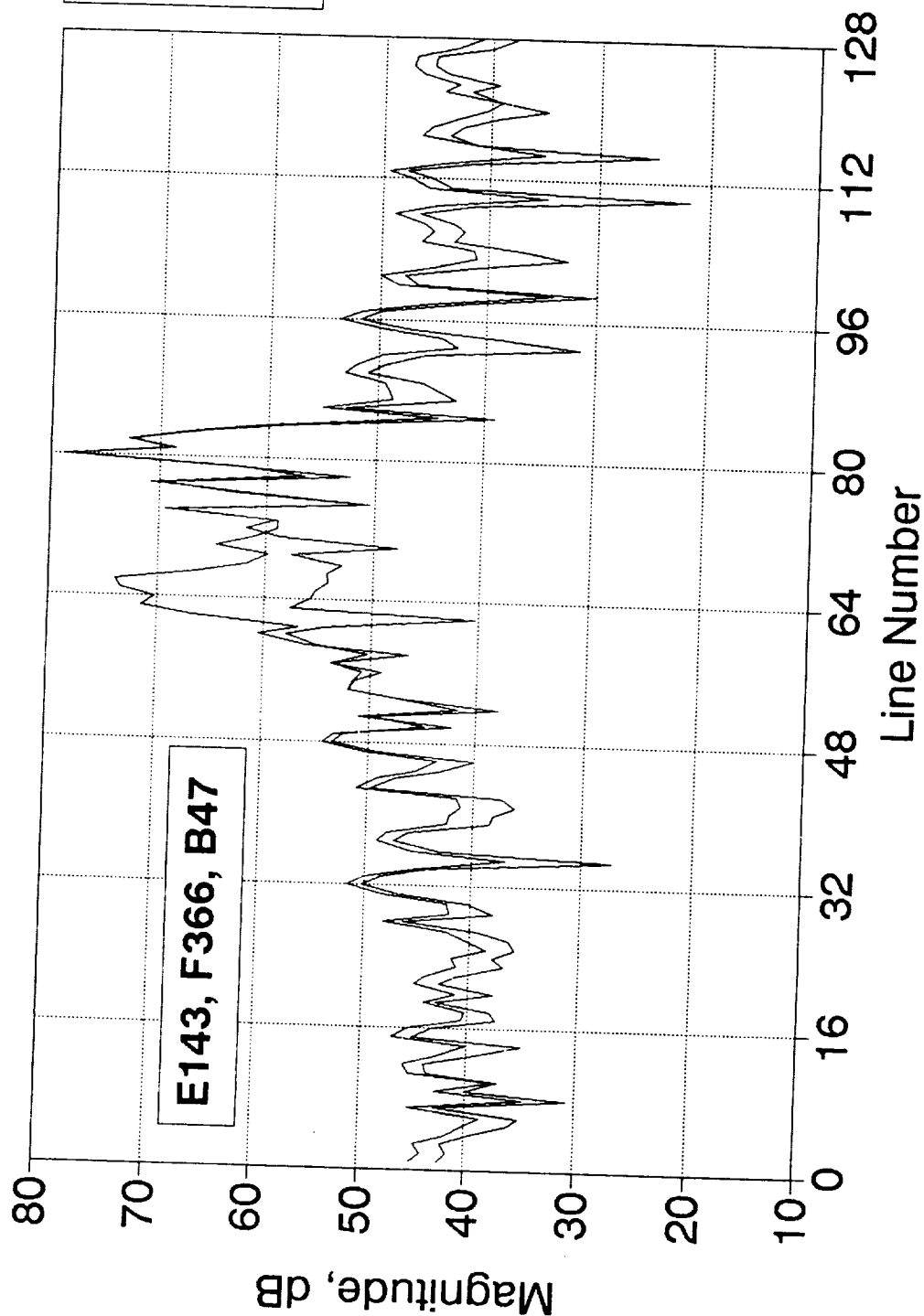
RECEIVED POWER VS. RANGE

SIGNAL PROCESSING ALGORITHMS



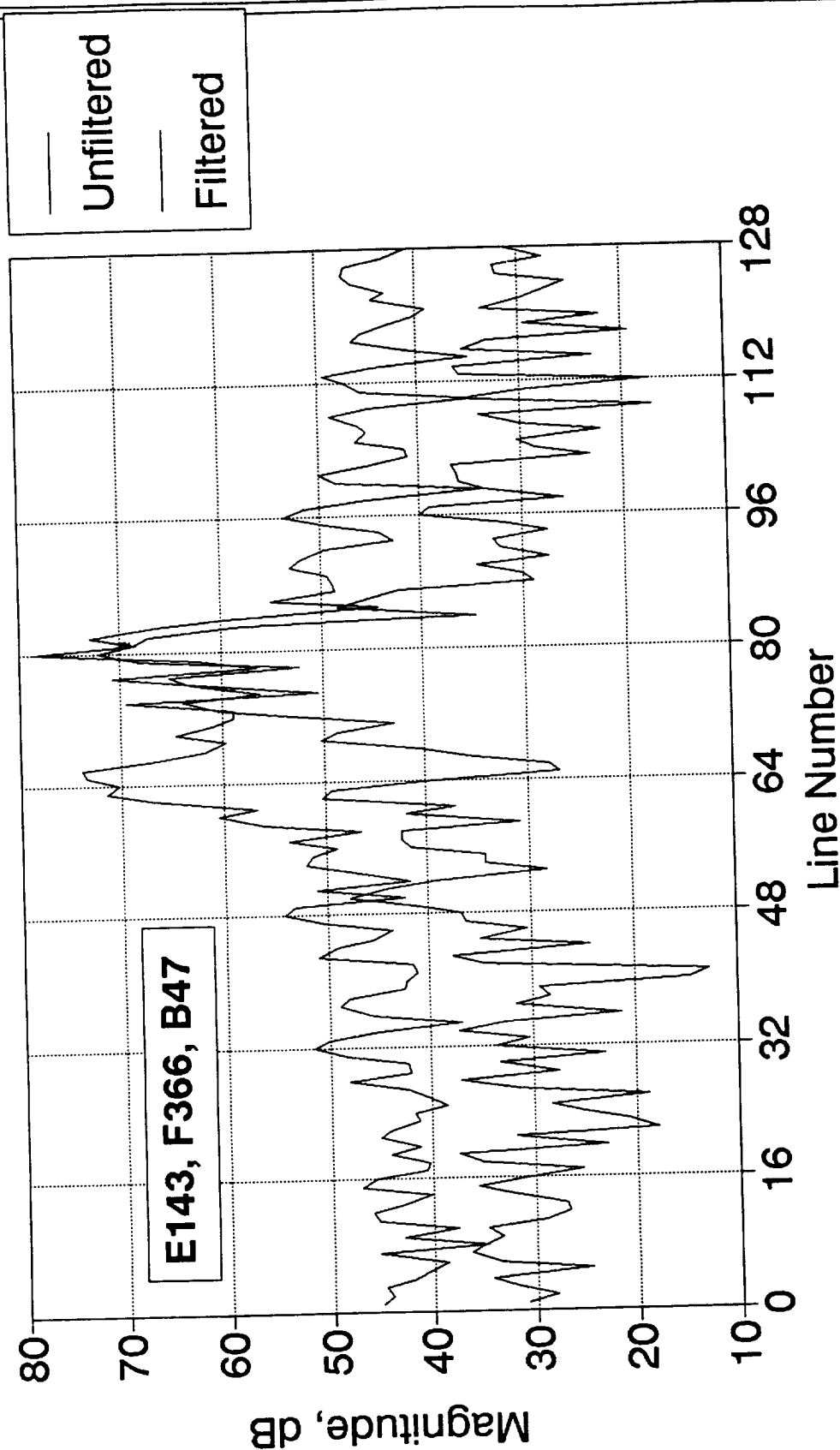
DOPPLER SPECTRUM

TD, No Wts., IIR-2 Filter



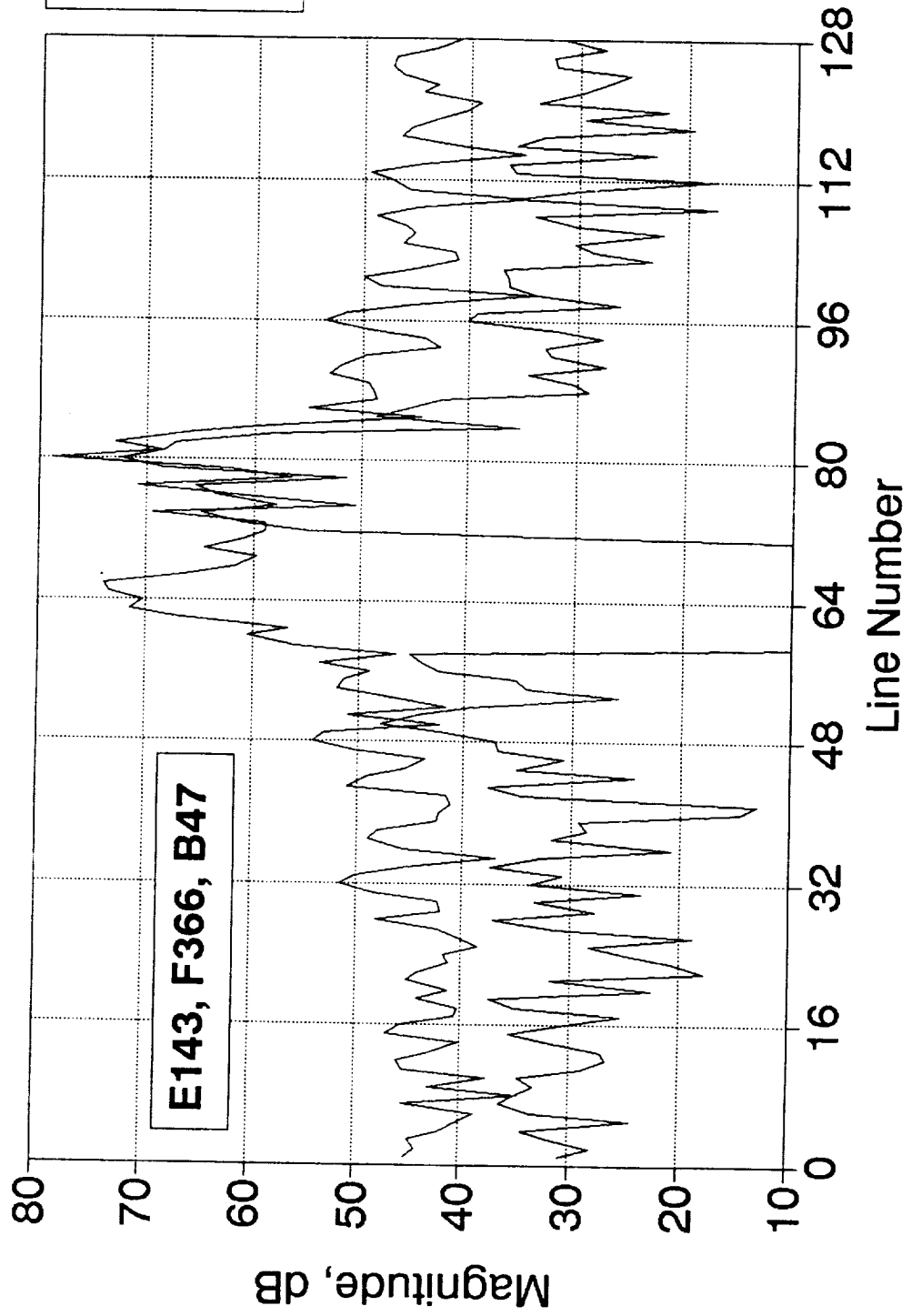
DOPPLER SPECTRUM

TD, Hann Wts., IIR-2 Filter



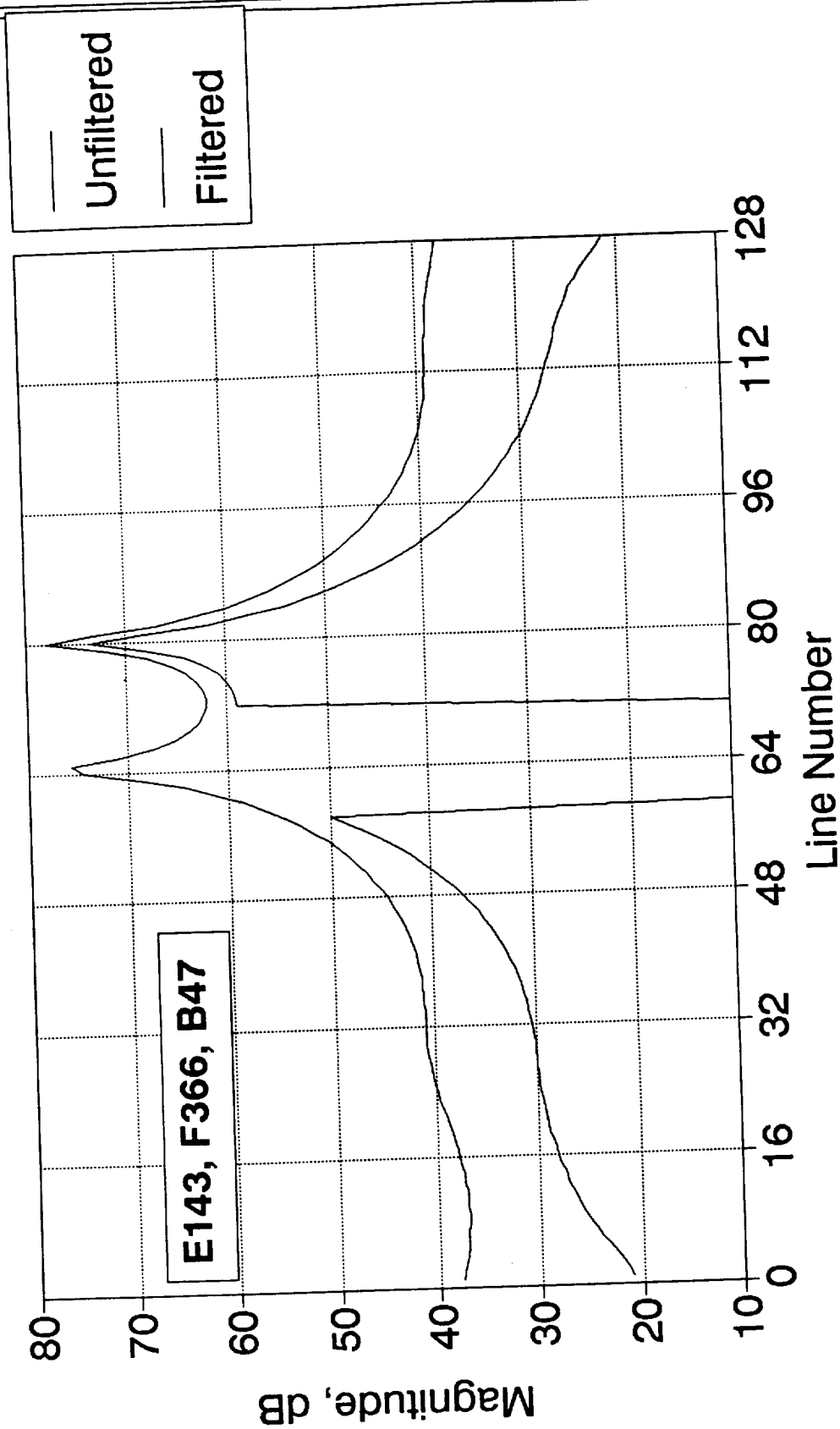
DOPPLER SPECTRUM

No TD Fil., FFT, Hann Wts., Line Edit



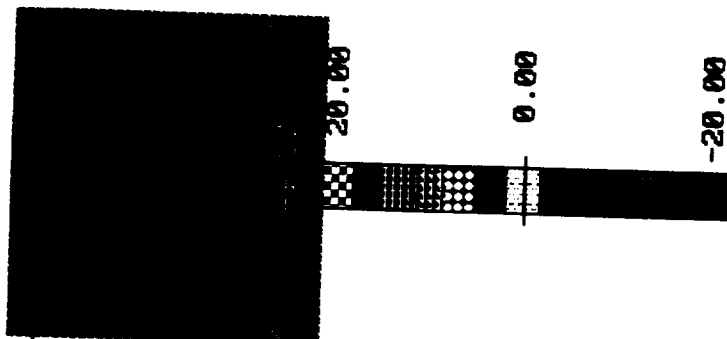
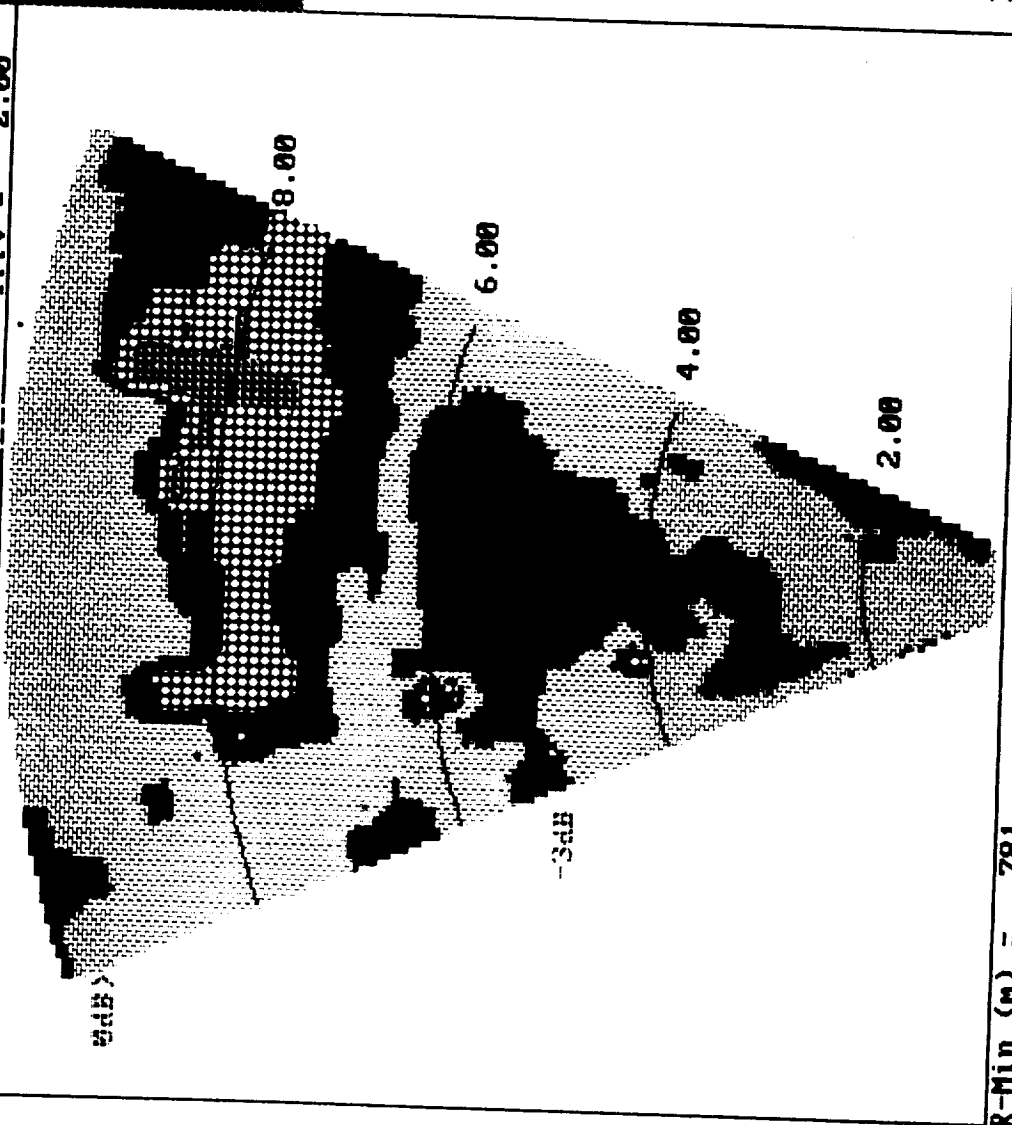
DOPPLER SPECTRUM

No TD Fil., Hann Wts., AR-5, Line Edit



TIME-DOMAIN FILTER - IIR 2, HANN, PP

R-Max (m) = 9991. Center = 0.00 Tilt = -2.00



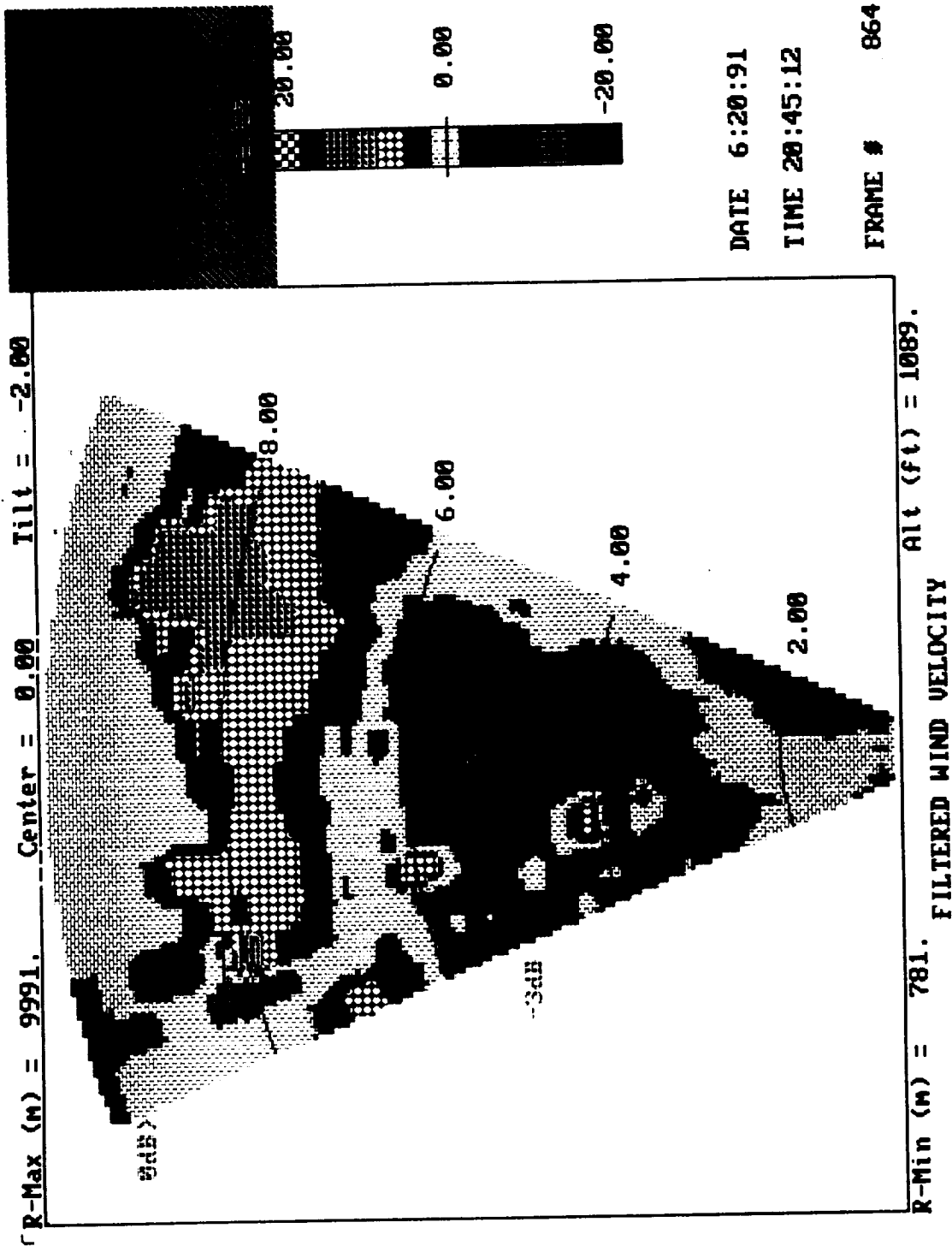
DATE 6:20:91

TIME 20:45:12

FRAME # 868

R-Min (m) = 781. FILTERED WIND VELOCITY Alt (ft) = 1089.

SPECTRAL DOMAIN FILTER - LINE EDIT



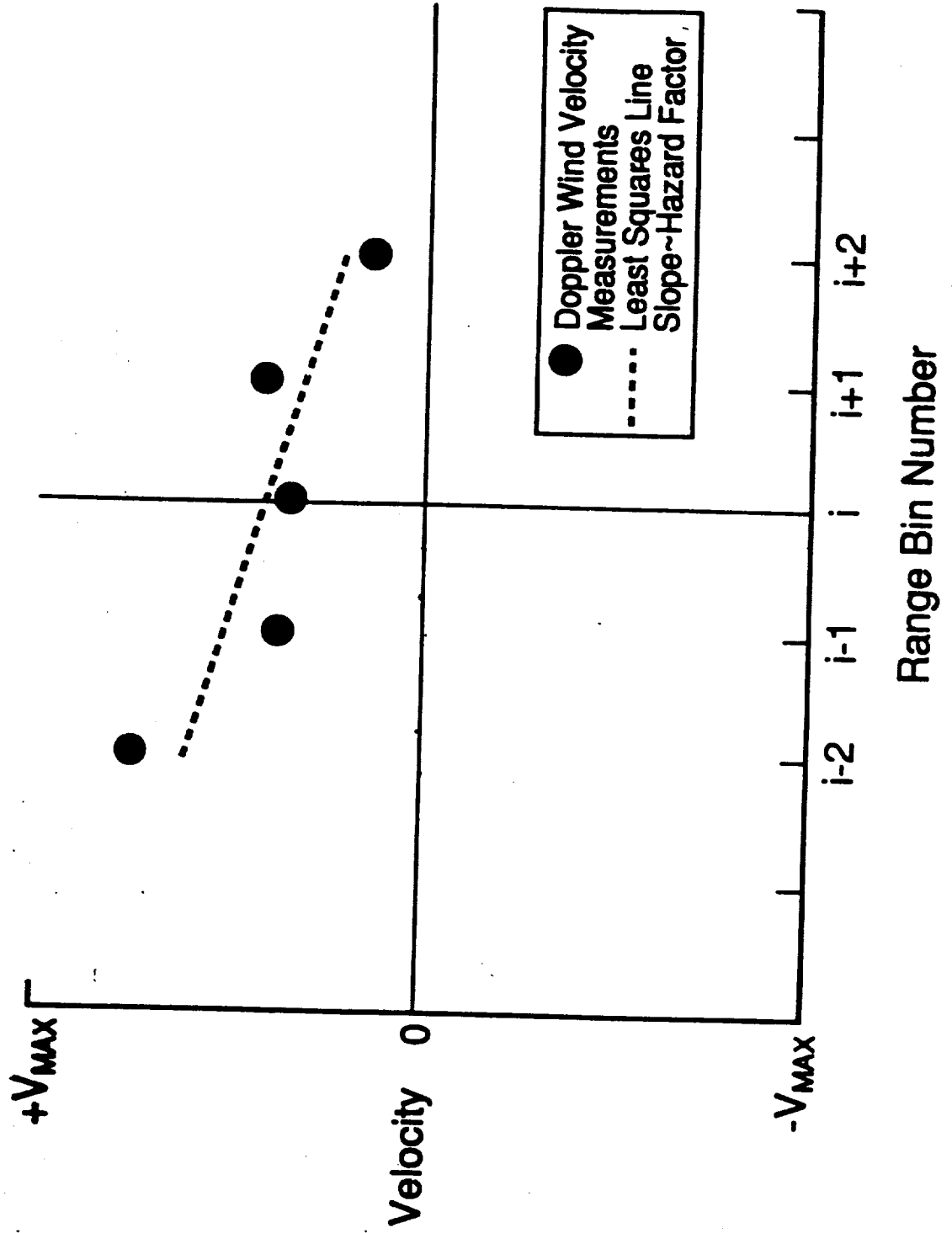
VALID VELOCITY MEASUREMENT

- 1. SIGNAL LEVEL ABOVE LEVEL THRESHOLD**
- 2. SPECTRAL WIDTH BELOW WIDTH THRESHOLD**
- 3. PROVISION FOR LOW-PASS FILTERING OF VELOCITY DATA**

CALCULATION OF HAZARD FACTOR

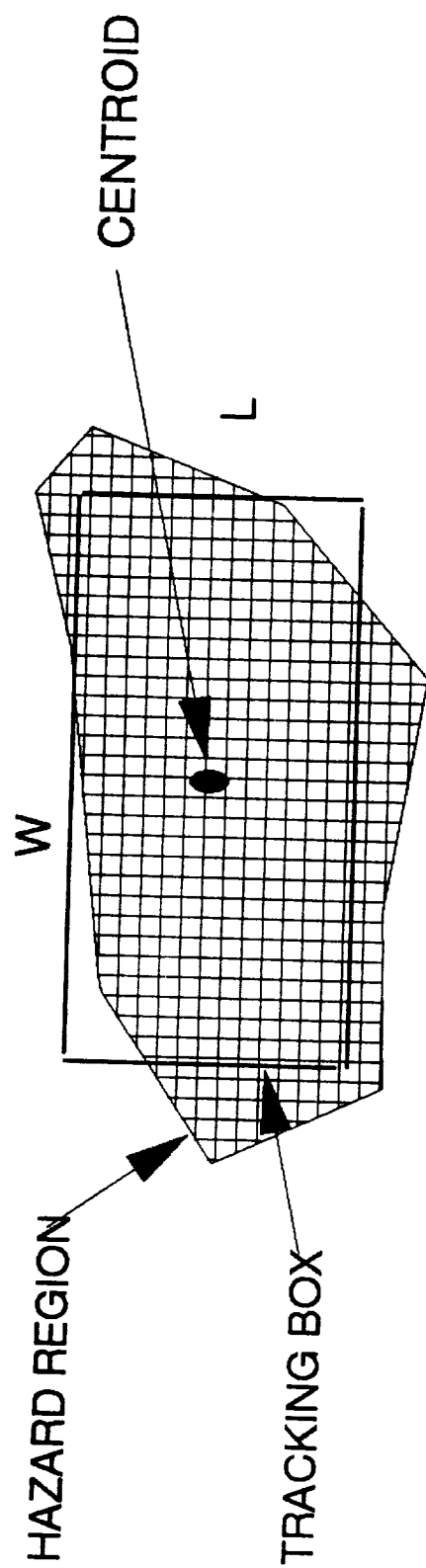
- 1. LEAST-SQUARES FIT TO VELOCITY OVER 5 RANGE BINS TO ESTIMATE VELOCITY SLOPE.**
- 2. VALID F-FACTOR CALCULATION IF LEAST-SQUARES RESIDUAL IS LESS THAN A RESIDUAL THRESHOLD.**
 - 2a . ALTERNATIVELY, A WEIGHTED LEAST-SQUARES ALGORITHM IS USED; WEIGHTS ARE SPECTRAL WIDTHS.**
- 3. FROM THE RADIAL F-FACTOR AND THE ALTITUDE OF THE RANGE CELL, THE VERTICAL F-FACTOR IS ESTIMATED AND ADDED TO THE RADIAL TO FIND THE TOTAL F-FACTOR.**

WEIGHTED LEAST SQUARES HAZARD ESTIMATOR

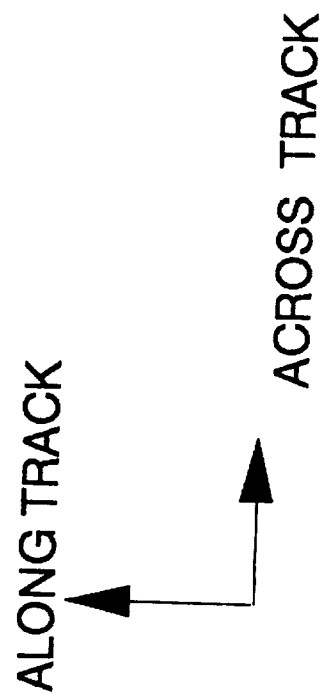


DETERMINATION OF HAZARD

- 1. AVERAGE THE BIN HAZARD FACTORS OVER A LENGTH OF APPROX. 1000 METERS.**
- 2. CALCULATE AREAS OF RADAR SCAN WITH HAZARD FACTOR ABOVE THE HAZARD FACTOR THRESHOLD.**
- 3. CALCULATE THE AREA OF THE HAZARD REGION.**
- 4. IF HAZARD REGION IS GREATER THAN AN AREA THRESHOLD, A HAZARD EXISTS IN THE SCAN.**



$L \times W = \text{AREA OF HAZARD REGION}$



WARNING CRITERIA

1. CENTROID OF HAZARD AREA IS TRACKED FROM
SCAN-TO-SCAN USING TRACK-WHILE-SCAN ALGORITHMS.
2. IF THE HAZARD REGION PERSISTS OVER THE
SCAN COUNT THRESHOLD, AND IF THE TIME-TO-CLOSEST-
APPROACH IS LESS THAN THE TIME THRESHOLD, AN
ALERT IS DISPLAYED.

SUMMARY OF BASELINE THRESHOLDS

SIGNAL LEVEL	>	-107 dBm
SPECTRAL WIDTH	<	8 m/s
TOTAL HAZARD INDEX	>	.105
LEAST-SQUARES RESIDUAL	<	3 m/s
AREA OF HAZARD	>	.2 sq km
SCAN COUNT	>	2
TIME-TO-CLOSEST APPROACH		10-40 secs

CONCLUSIONS

- USING BASELINE ALGORITHMS & THRESHOLDS ON FLIGHT AND SIMULATED DATA GIVES:
 - NO FALSE ALARMS ON CLUTTER
 - TIMELY ALERTS ON ORLANDO WET MICROBURSTS
 - AND SIMULATED DENVER DRY MICROBURSTS
- ADDITIONAL DATA RUNS REQUIRED TO SELECT BEST SIGNAL PROCESSING ALGORITHMS
- DIFFERENCES IN PROCESSING ALGORITHMS ARE SUBTLE - A FIGURE OF MERIT IS NEEDED FOR PROPER EVALUATION

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Questions and Answers

Unknown - When you weight the least squares fit for shear on spectral width, isn't that going to make you unduly sensitive to any clutter that does get through your other filtering? I assume a false return would have very low spectral width wouldn't it?

A: Les Britt (RTI) - Yes, you are right. There have been suggestions to threshold on both ends of the spectral width, on very narrow spectral widths which may be a moving target and on the high end too, which is noise.